Tevatron Since May 1 and Future Plans

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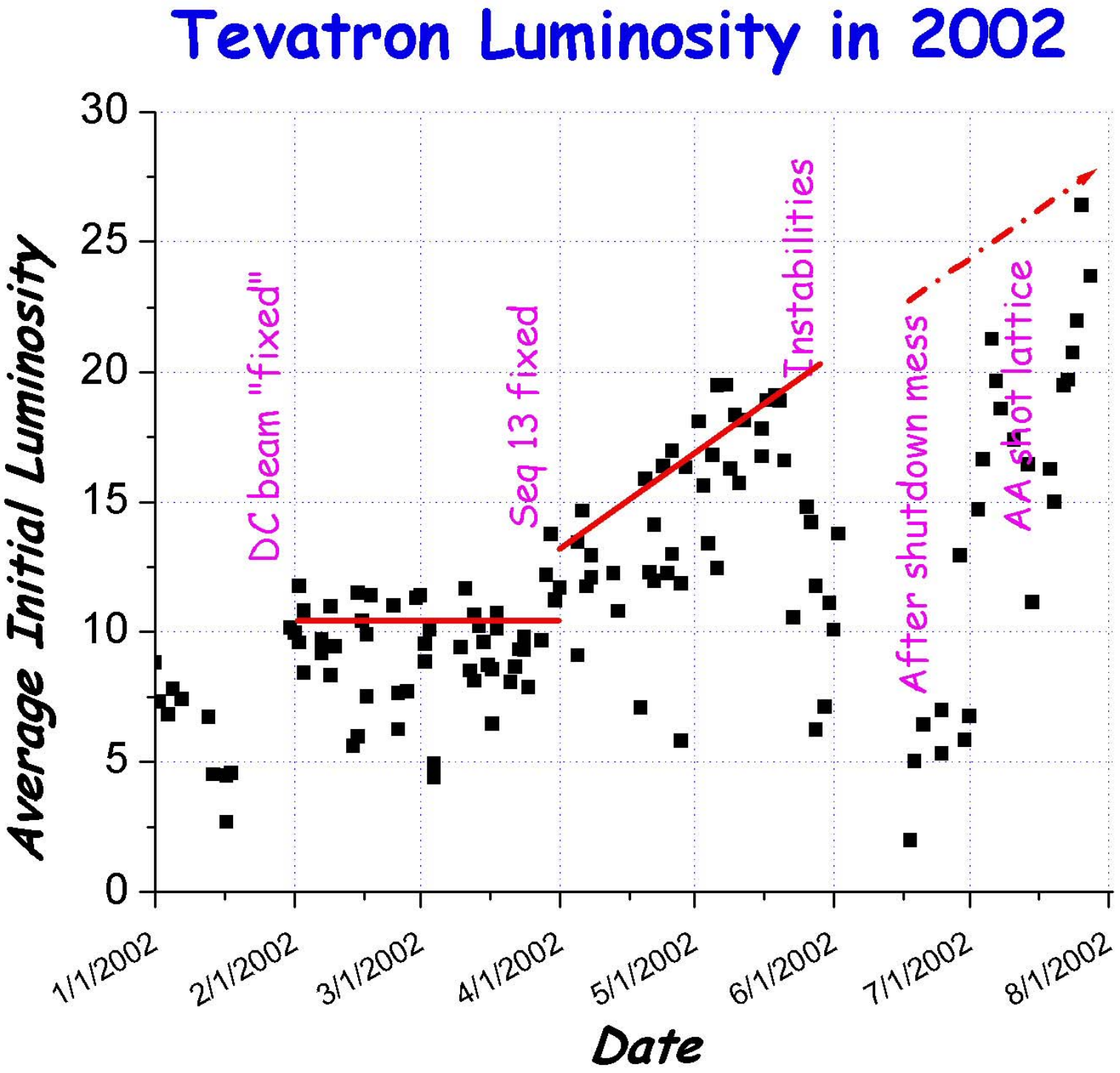
1. Introductory remarks: May 1st vs August 1st

2. Tev issues/studies: Beam-beam effects
   Instabilities
   Losses/Background

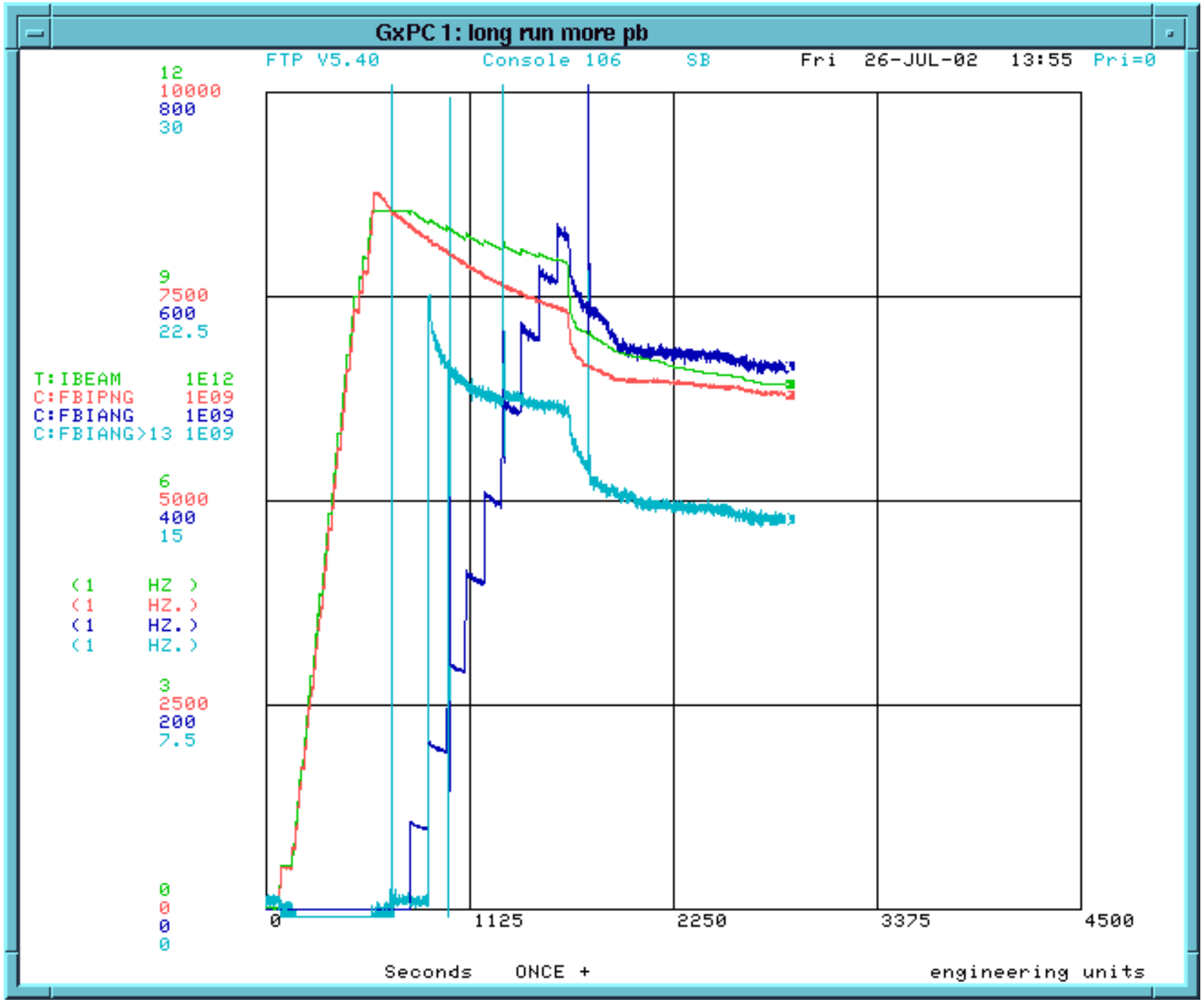

Tevatron Luminosity in 2002
Average Initial Luminosity
30
25
20
15
10
5
0
DC beam "fixed"
Seq 13 fixed
Instabilities
After shutdown mess
AA shot lattice
1/1/2002
2/1/2002
3/1/2002
4/1/2002
5/1/2002
6/1/2002
7/1/2002
8/1/2002
Date

record *L* stores

	May'02 #1289-1337	July'02 #1501-1594	Δ, %	#1303	#1583	Δ, %
N_p, e9	6260	6375	+1.8	6075	6300	+3.7
N_a, e9	410	486	+11.7	486	530	+9.1
Out AA,mA				103	116	+12.6
ε_eff,π	20.7	19.7	-4.8	21.5	15.8	-26.3
L, e30	17.6	20.9	+18.6	19.6	26.4	+35.4

→ major factor affecting *L* is emittance, then pbar intensity
(more due to larger stack than due to better xfer efficiency)

Illustration of losses: record L=26.4e30 store #1583



Is Tevatron more friendly to p- and pbar-beams? NO !

Step loss	May'02 #1289-1337	July'02 #1501-1594	Δ
Pbar @ 150	18.3%	16.4%	-1.9%
Pbar on ramp	11.6%	11.8%	+0.2%
Pbar squeeze	4.1%	9.6%	+5.5% !
Protons @ 150	16.3%	15.4%	-0.9%
P's on ramp	6.4%	11.6%	+5.2% !

* numbers for record stores are similar

Tevatron issues (in scale):

Beam-beam effects

N_p effect
Emittance+aperture effects
Tune, κ, C_v,h, orbit effects
Lifetime in collisions

Instabilities

Coherent transverse and longitudinal
Incoherent transverse and longitudinal

Detector backround

Losses due to vacuum and DC beam

Beam-Beam #1: N_p effect

* pbar losses depend on proton intensity:

- without protons pbar loss in Tev is <10% 9 (total)

-

Store	*N_p, e9*	*Out of AA, mA*	*Loss at 150*	*Loss on ramp*	*Loss in squeeze*	*Pbars at low-beta*	*L, e30*
1303	6070	103	16.4%	11.6%	3%	476	19.5
1289	6990	105	18%	20%	11%	387	19.6

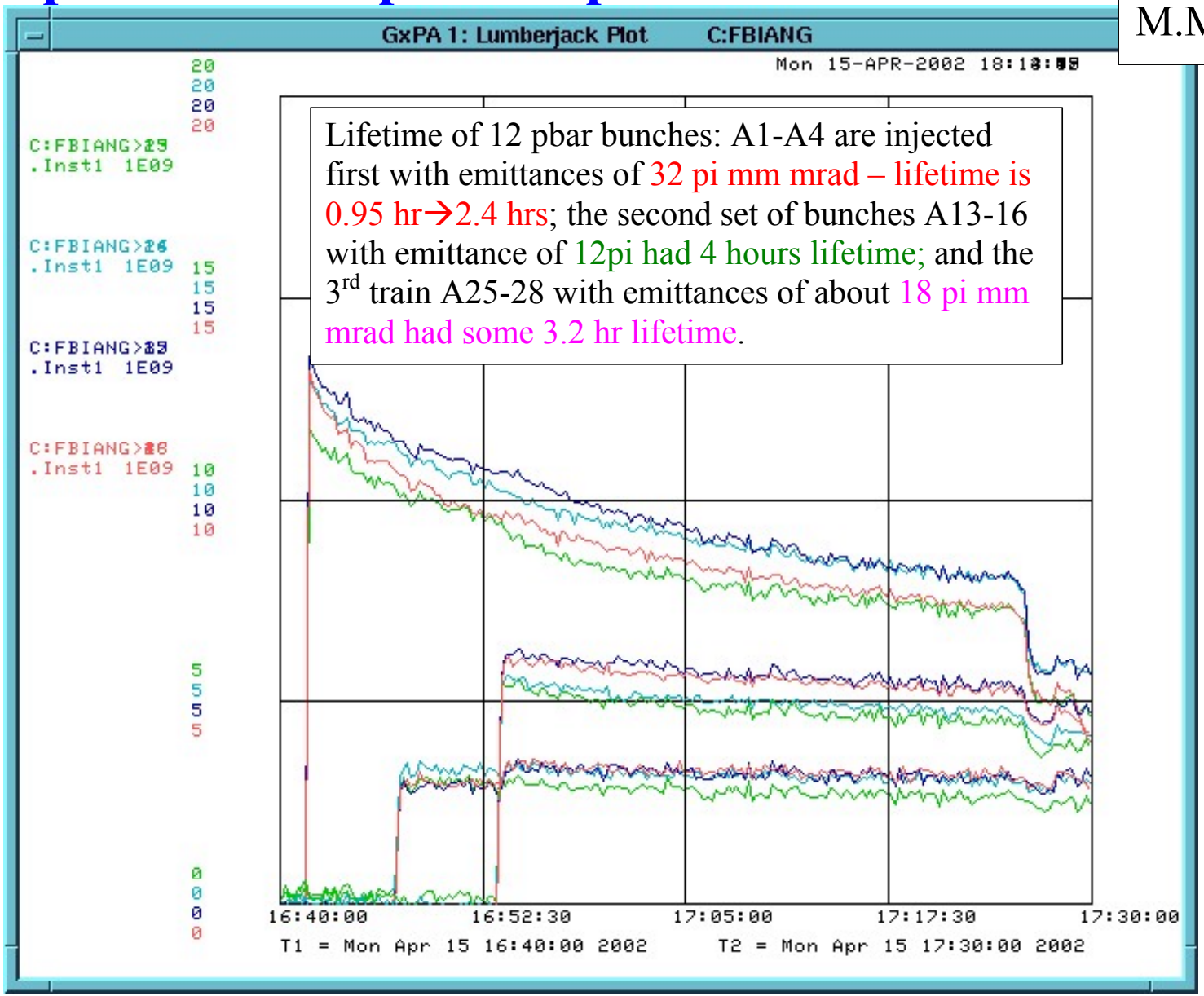
+protons are less stable at high N_p, blow-up pbar ε_x,y

- we do not force higher N_p until dampers installed (Jim Steimel, C.-Y. Tan) – Oct '02
- continue beam-beam vs N_p studies (T.Sen) -2 mos

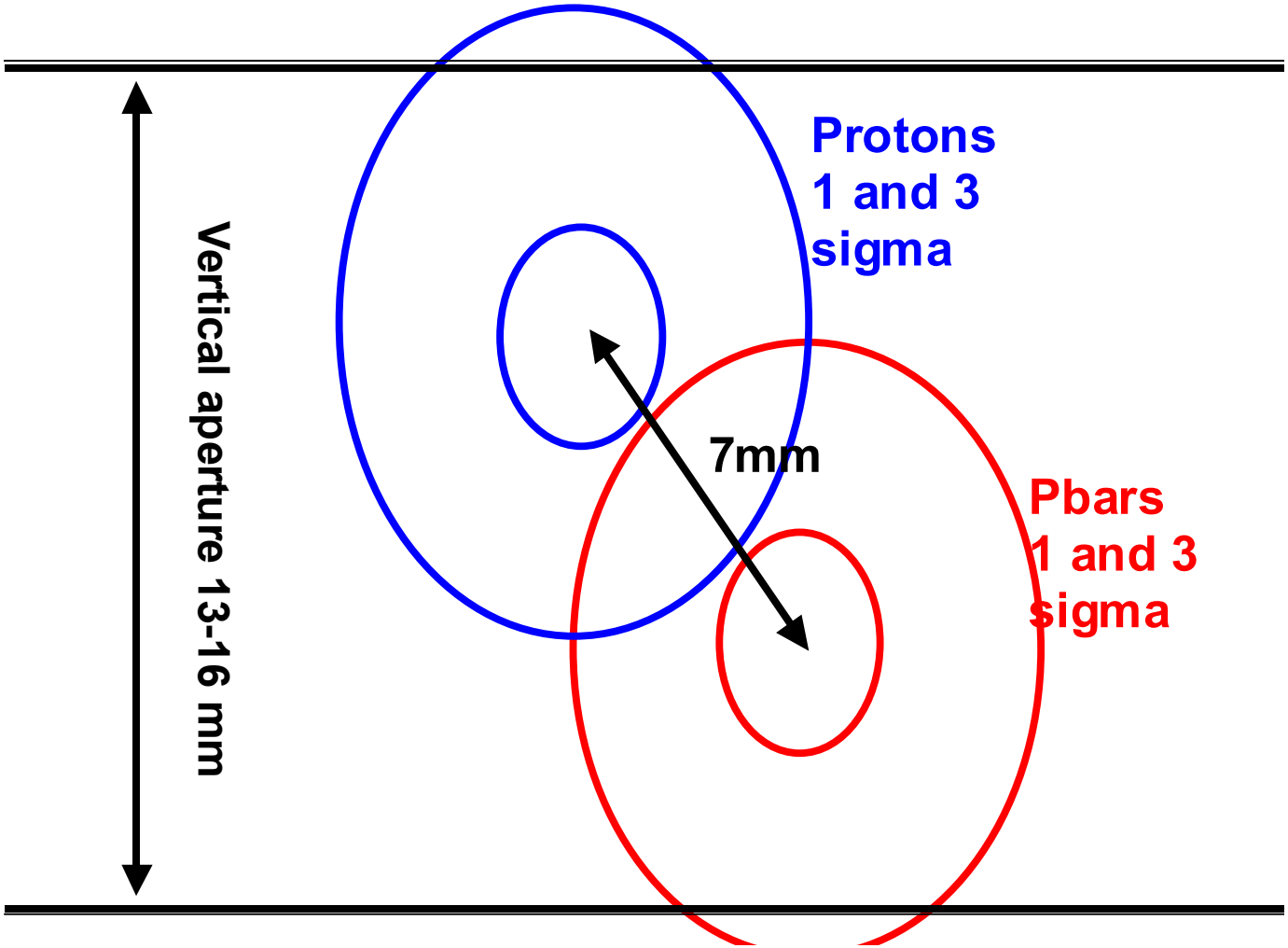
Beam-Beam #2: Emittance/Aperture effect

* pbar losses depend on pbar beam size:

M.Martens, 4/2002

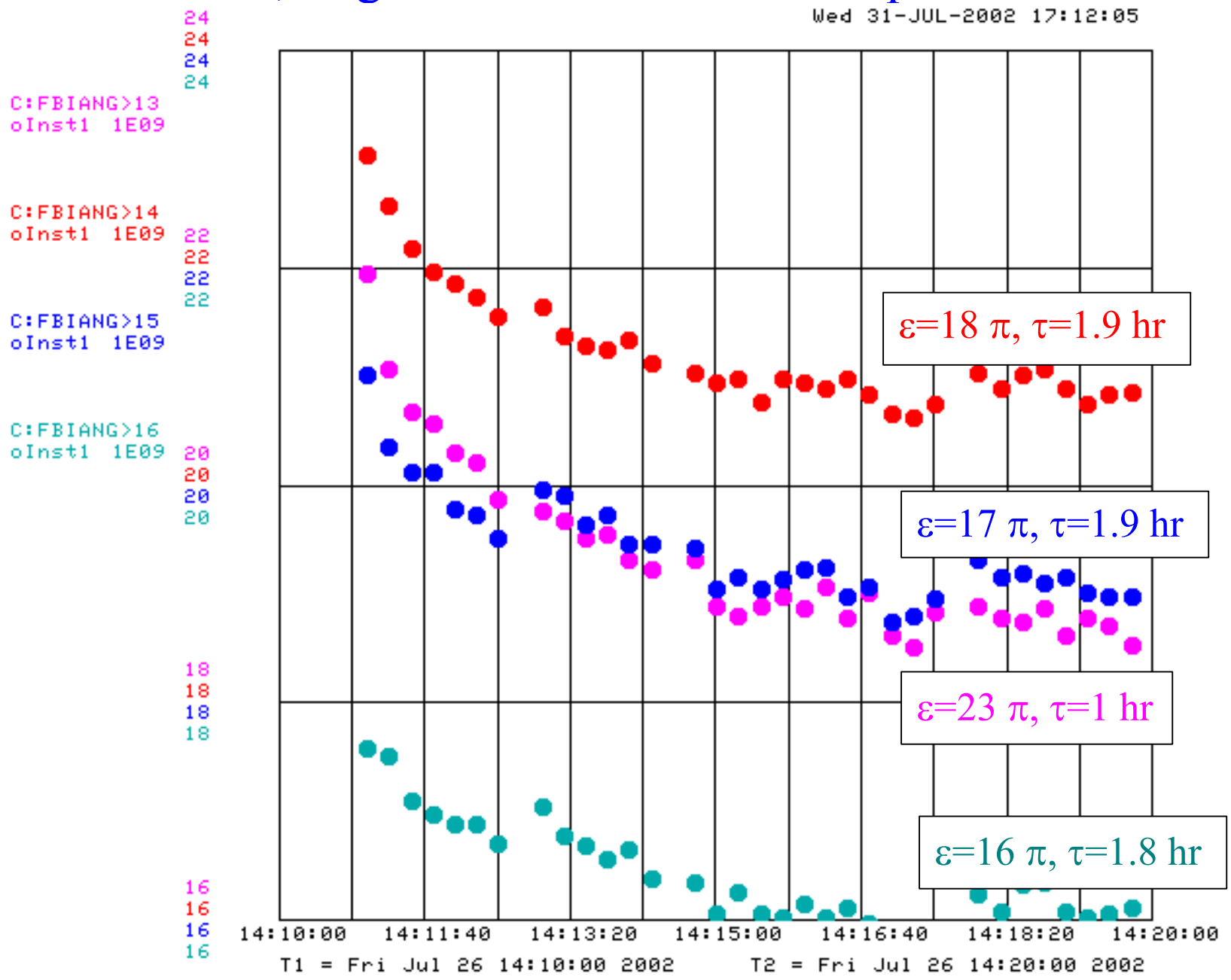


- our understanding of 150 GeV pbar issues was:



pbars are too close to protons (~4σ) which work as **"soft collimator"** , but physical aperture at C0 Lambertson is tight, too. Options: increase separation (tilting helix), reduce sigma, increase aperture, inject faster. We tried the first approach without big success and recently found that smaller ε do not help much (yet) .

- store 1583, large emittance variation in pbar train



- our plans concerning this effect are:
  1. reduce pbar emittance dilution at injection by doing beter closure (BLT work, Jerry and Vic) and optimizing A1 line (Valery, D.Johnson) -few mos
  2. fix inj-"bumper" which kicks p's (Bruce) - ASAP
  3. built injection dampers (J.Steimel,C.Y.Tan) –5mos
  4. replace C0 Lamberson magnets with MI dipoles to double vertical aperture (1"→2") and allow larger separation at 150 GeV (P.Garbincius, Bruce) – next big shutdown (Oct? Jan?)
  5. study possibilities of changing optics and improve minimal beam-beam separation (Aimin Xiao, Valery, Yuri, John Johnstone) – in ½ year
  6. finish SyncLite commissioning (Cheung) –1-2mos
  7. continue attempts to develop a tracking code with some descriptive and predictive power (T.Sen, M.Xiao, B.Erdelyi, SLAC guys) – 1 year(?)

Beam-Beam #3: Effects of Q_x,y, coupling, C_v,h, orbits

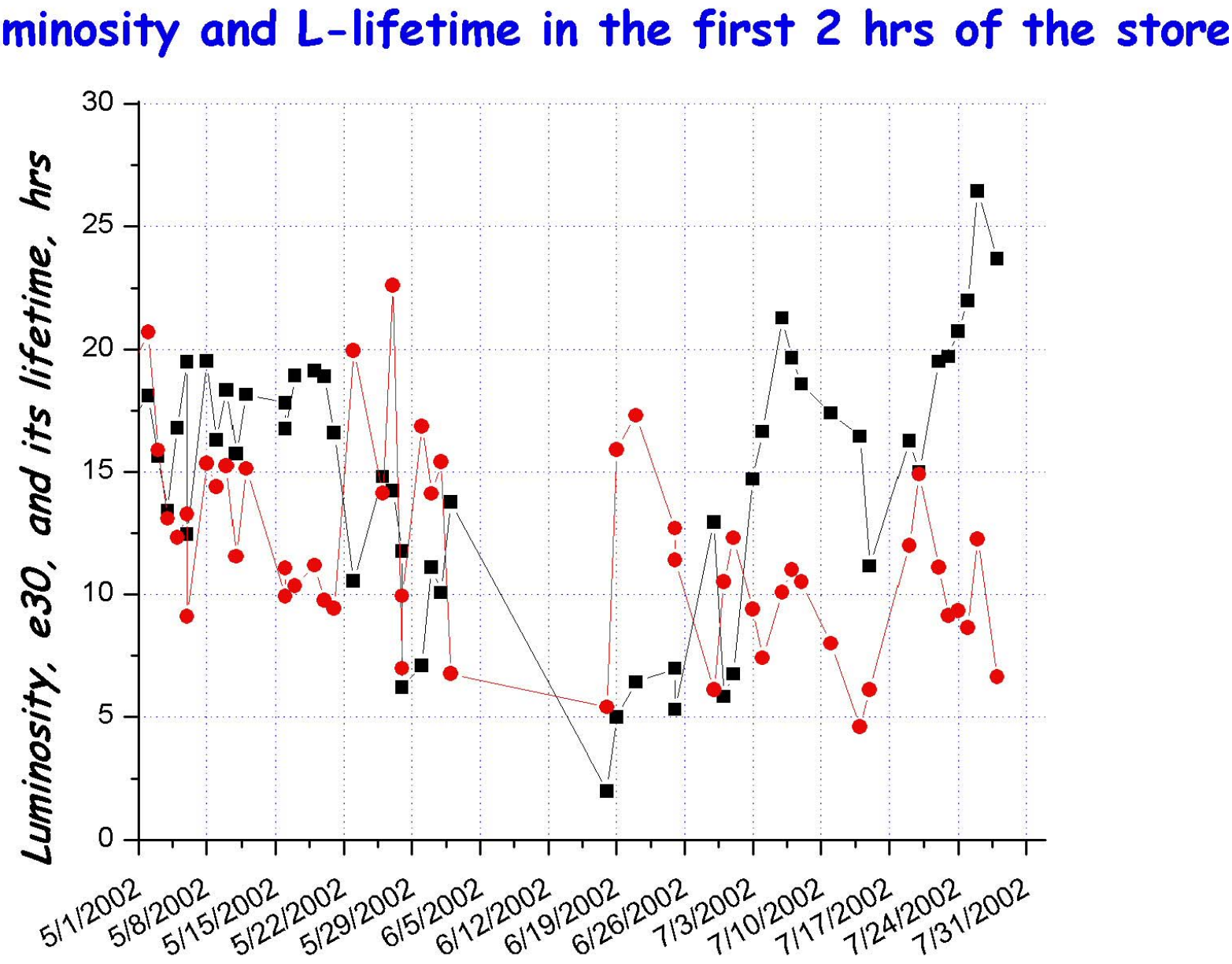
- numerous observations point to importance of keeping p(and pbar) tunes near "good" tunes of Q_x,y=0.575/0.583 (within about +- 0.002) otherwise losses become high
- tunes are affected by coupling and orbit deviations from a "silver orbit"
- smaller chromaticity C_v,h → smaller losses, so we try to keep chromaticities as low as possible without allowing beam to go unstable
- now, the problem is that nothing is stable: a) chromaticities (b_2 in dipoles) depend time at 150 GeV due to persistent currents – and we compensate that by slowly varying currents in sextupole circuits (Run I); b) new in Run II – tunes and coupling vary similarly (! – see Figs);

c) orbits drift at the rate about 1 mm/sqrt(month) (- see Figs) and we regularly smooth them – the procedure is very time consuming (parsing) but worthwhile.

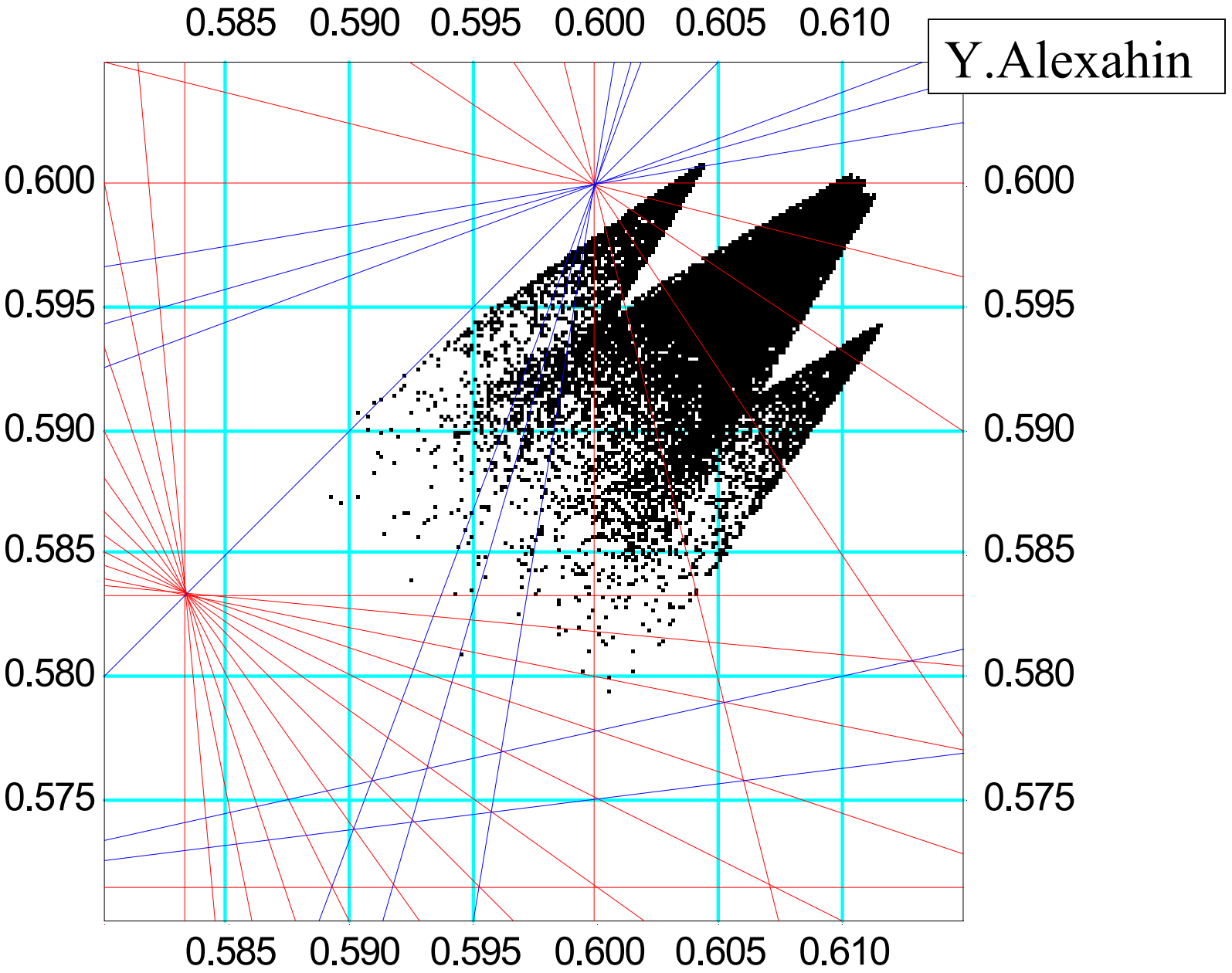
- issues to address:

1. drifts of tunes and coupling will be compensated (Mike M and Jerry) – in 1-2 wks
2. new p and pbar Schottky detectors at E17 (RFI) – next shutdown
3. on-line tune stabilization feedback like in RHIC (??, BNL??) – in ½-1 year
4. redo C_v,h jump compensation (Tev) –TBD
5. McGinnis C_v,h technique (Dave+Jerry) –soon
6. differential chromaticity for p and pbars (Yuri) – if necessary.

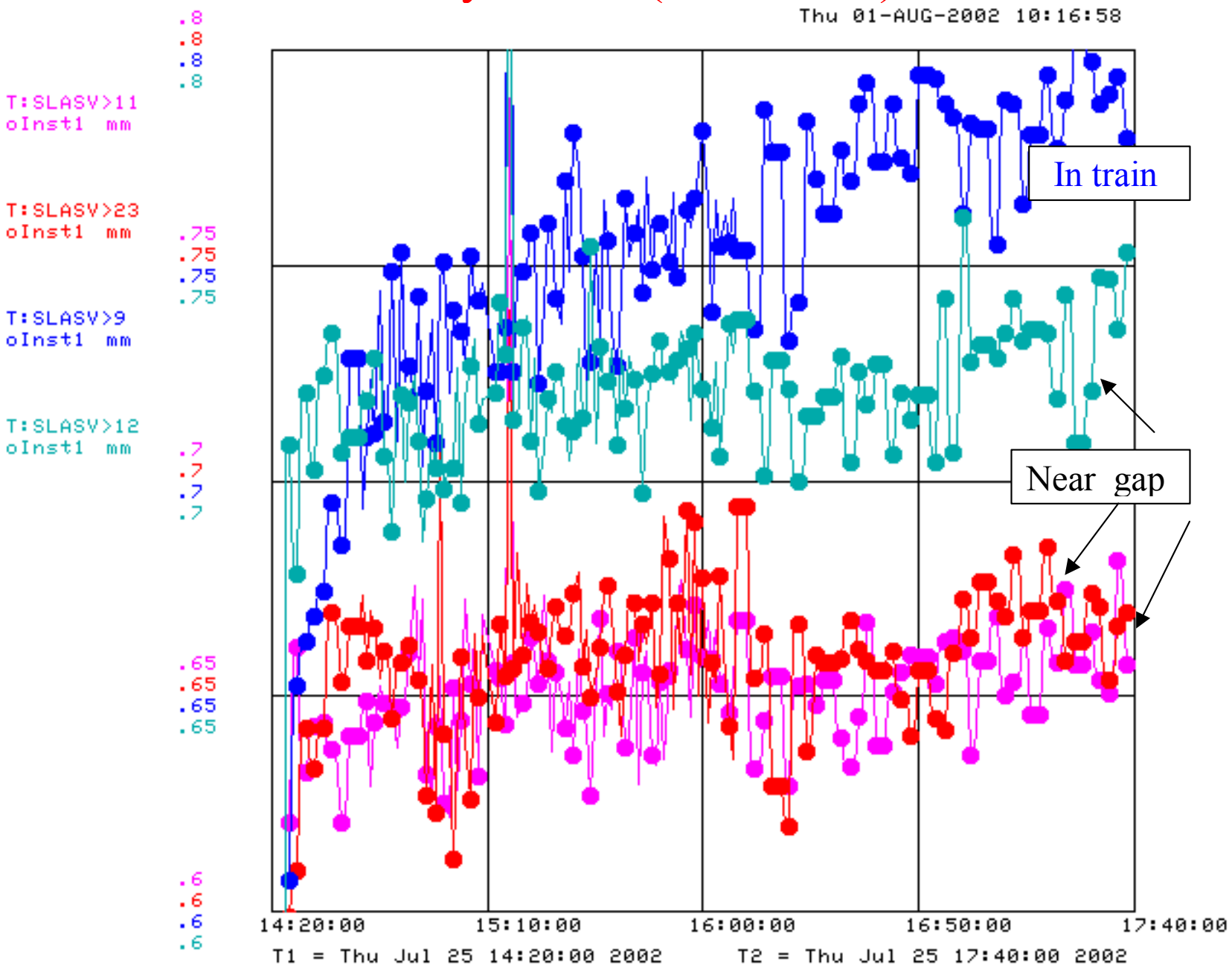
Beam-Beam #4: Luminosity lifetime (anticorrelates with *L*)



- either problem with pbar beam size and losses



→ different bunch dynamics (store 1580)



- … or, in the last 4 stores #1583-1612 τ_L was <7 hours (early in store) due to poor proton lifetime, tune optimization did not help → longitudinal shaving?
- our future steps concerning lifetime:

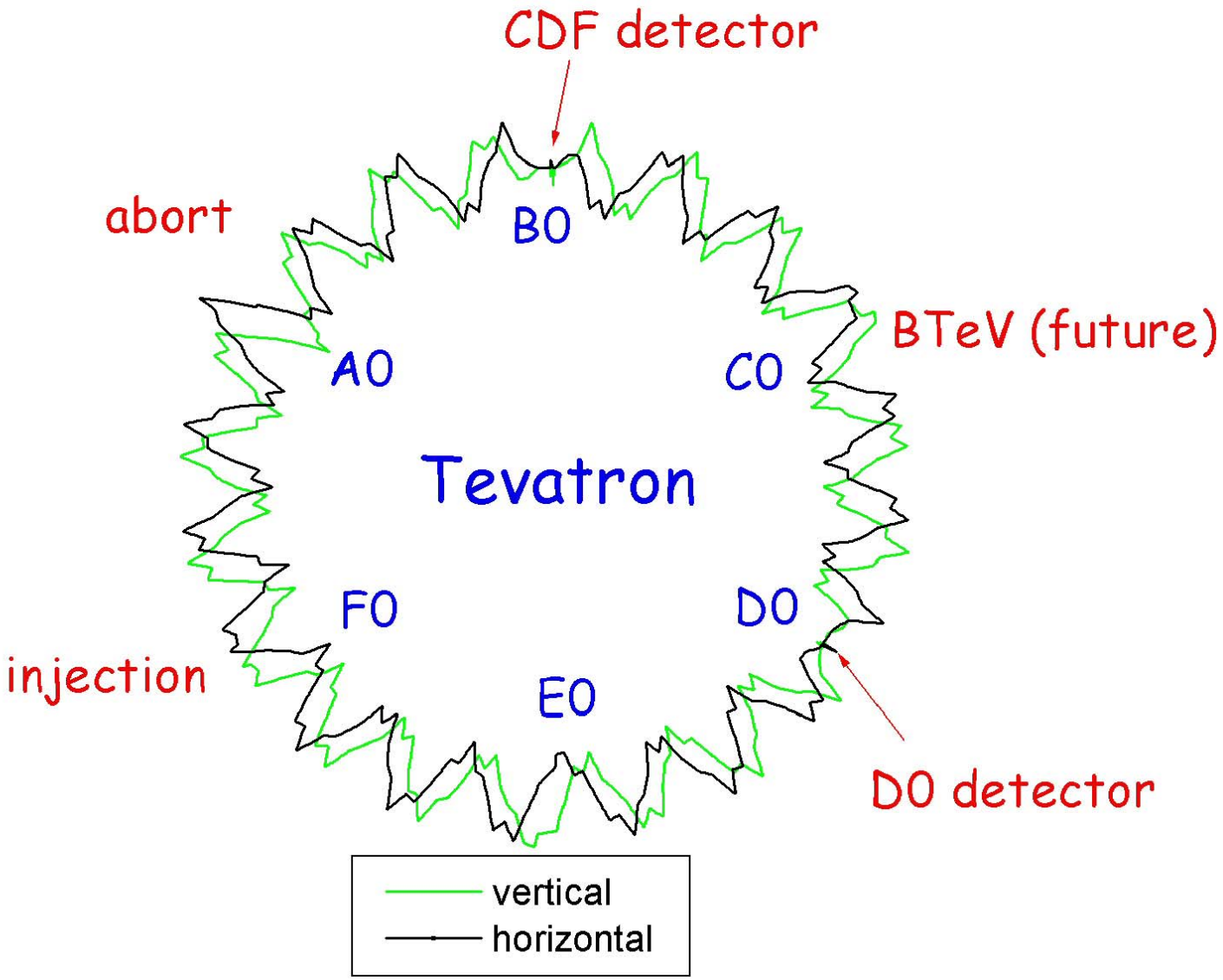
1. goal = bring lifetime back to Run I value of 9-10 hrs in the first 2 hours, and >15 afterward

2. explore larger helix separation: T.Sen studies suggest significant lifetime improvement even with 10-15% helix increase (TeV) – few mos

3. optimize tunes for most of bunches (TeV) – ASAP

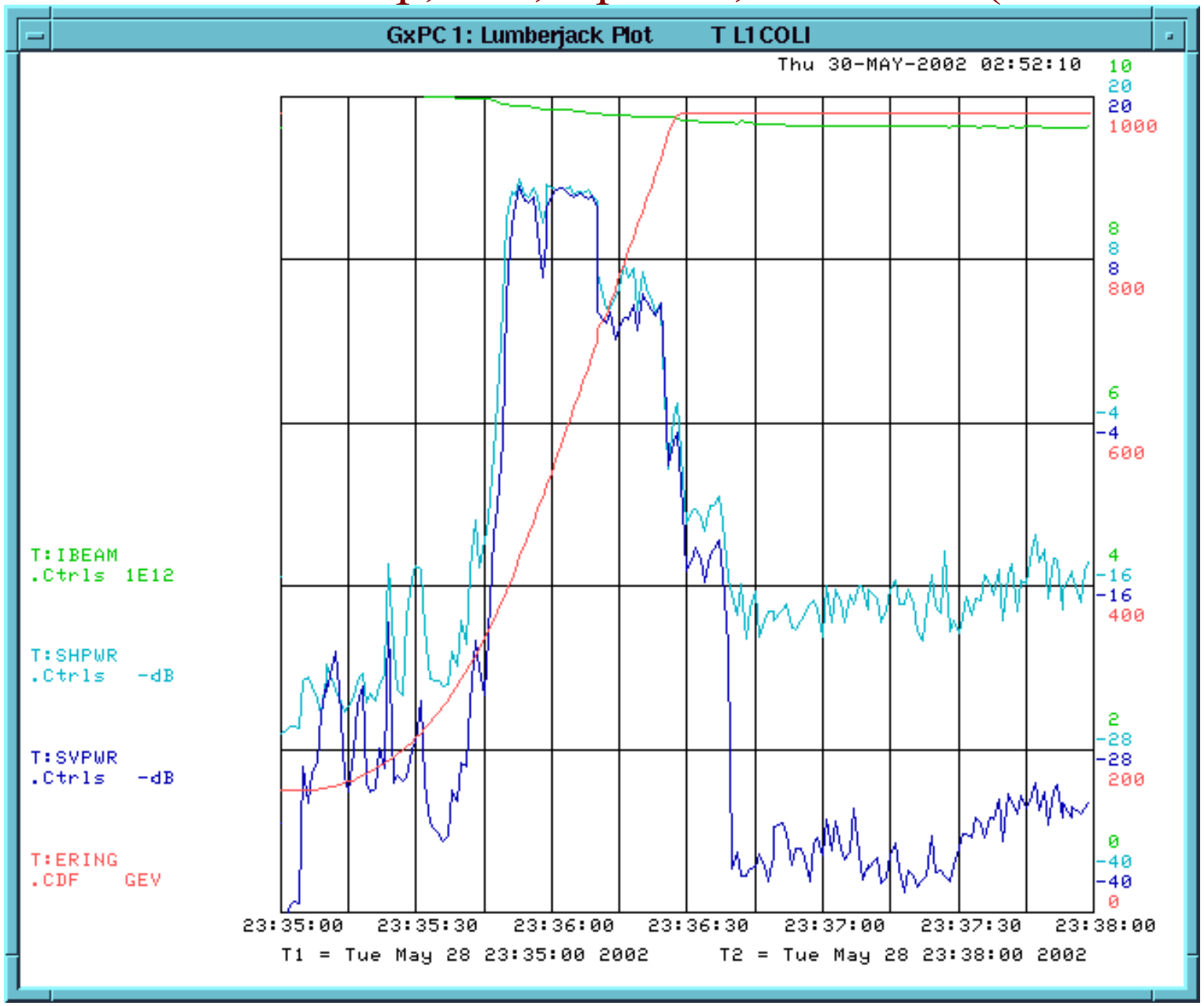
4. continue studies of Beam-Beam Compensation with TEL (BBC project group) – ongoing; build the 2nd TEL? (1 year)

Tevatron Collision Helix



Instabilities #1: Coherent: a) transverse

- occurs on ramp, 980, squeeze, collisions (see #1368)



Signatures:

- hor or vert Schottky power goes way up
- p-emittance goes up (from 25 to 30-35 pi)
- pbar emittance goes up (25-30 to 45-80 pi)
- severe since after May 21 (?)

Facts:

a) depends on proton intensity (often observed at N_p > 5800...7500e9)

b) occurs at 150 , ramp, 980 GeV

c) can be suppressed by increase of C_v,h (not always)

d) can be eased by changing coupling SQ or/and tunes (not always)

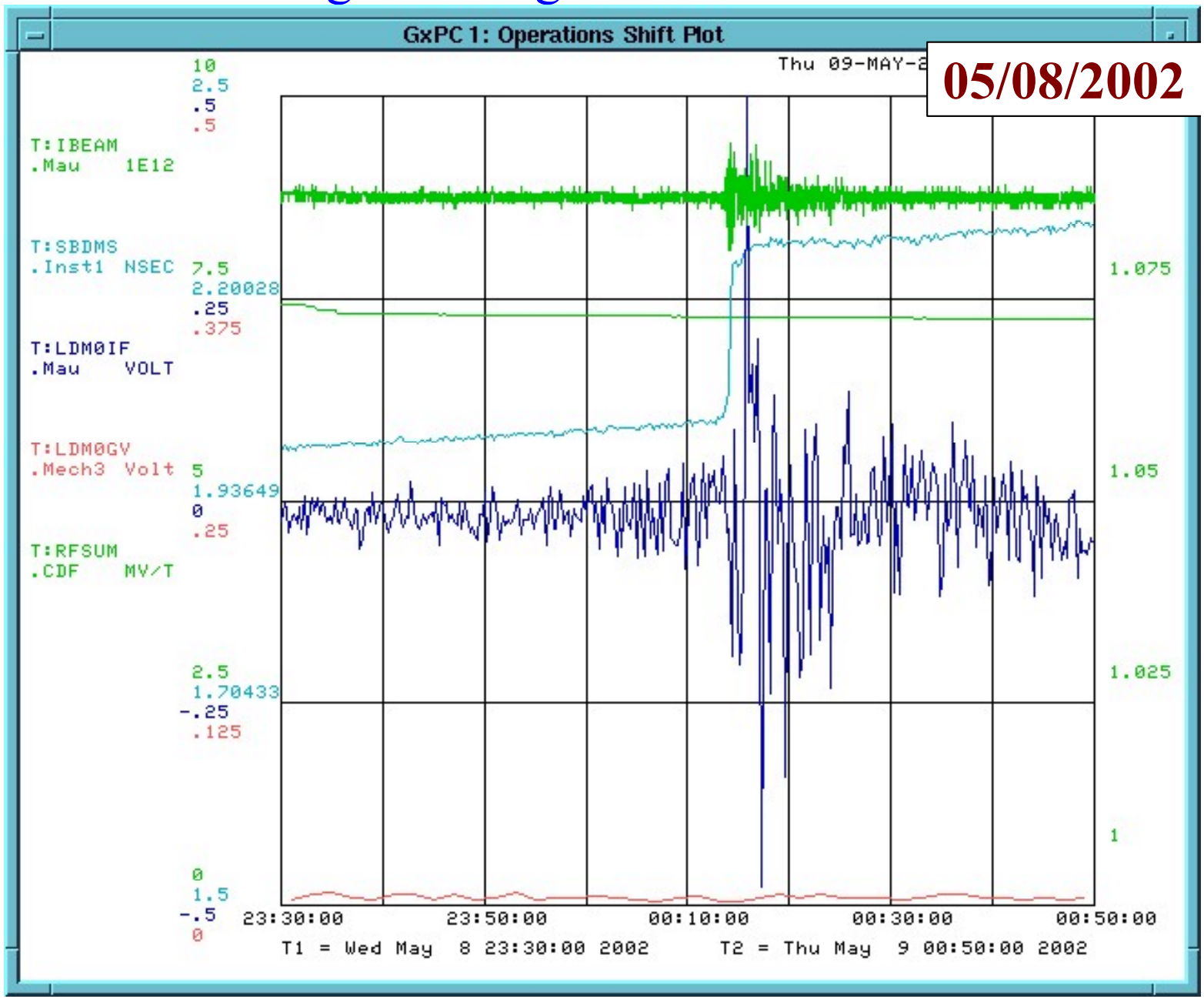
e) seems to be single bunch phenomena

f) sometimes one of higher order SB lines goes coherent

→ (higher SB-mode) "weak" head-tail in x-y coupled motion of high intensity p-beam

Coherent: b) longitudinal at 980 (see #1368)

* results in higher background rate and more DC beam



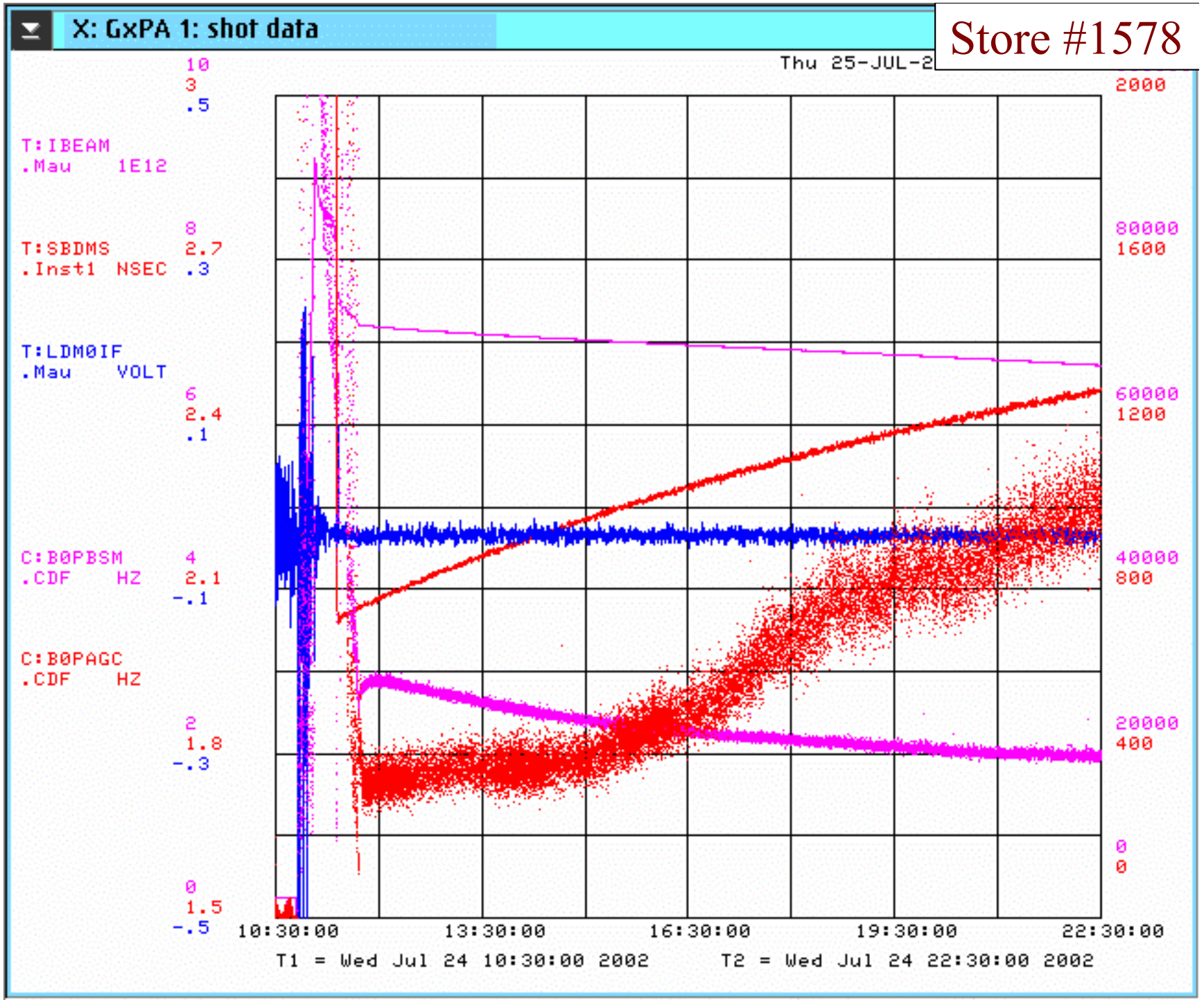
"~Facts" about the sigma_s blow-up:

1. 8 events in 12 stores in May'02, intensity dependent

A	B	C	D	E	F	G	H
1302 8 May 230	170e9	2.0ns	2.3 ns	60 min	42hrs	67hrs	bad
1305 9 May 190	167e9	2.0ns	2.3ns	6 min	12hrs	43hrs	bad
1307 10May 180	179e9	2.0ns			53hrs		good
1309 11May 130	171e9	2.0ns			42hrs		good
1313 12May 060	176e9	2.0ns			40hrs		good
1328 16May0200	186e9	?	?	?	?	bad. SBDMS data not recor	
1329 16May1800	176e9	1.9ns	2.2ns	3 min	??	77 hrs	really bad
1332 17May1930	178e9	1.9ns	2.4ns	6 min	9hrs	83 hrs	really bad
1333 18May 173	181e9	2.1ns			50hrs		good
1335 19May1200	177e9	2.0ns	2.2ns	39 min	40hrs	59 hrs	bad
1337 20May0540	183e9	2.0ns	2.2ns	16 min	19hrs	56 hrs	bad
1340 21May0200	194e9	2.0ns	2.6ns	2 min	?	?	really bad

A – store, date, time; B- total N_p; C, D- sigma_s before and after the blow-up; E- time in the store; F, G- $d\sigma/dt$ before and after, H-comment

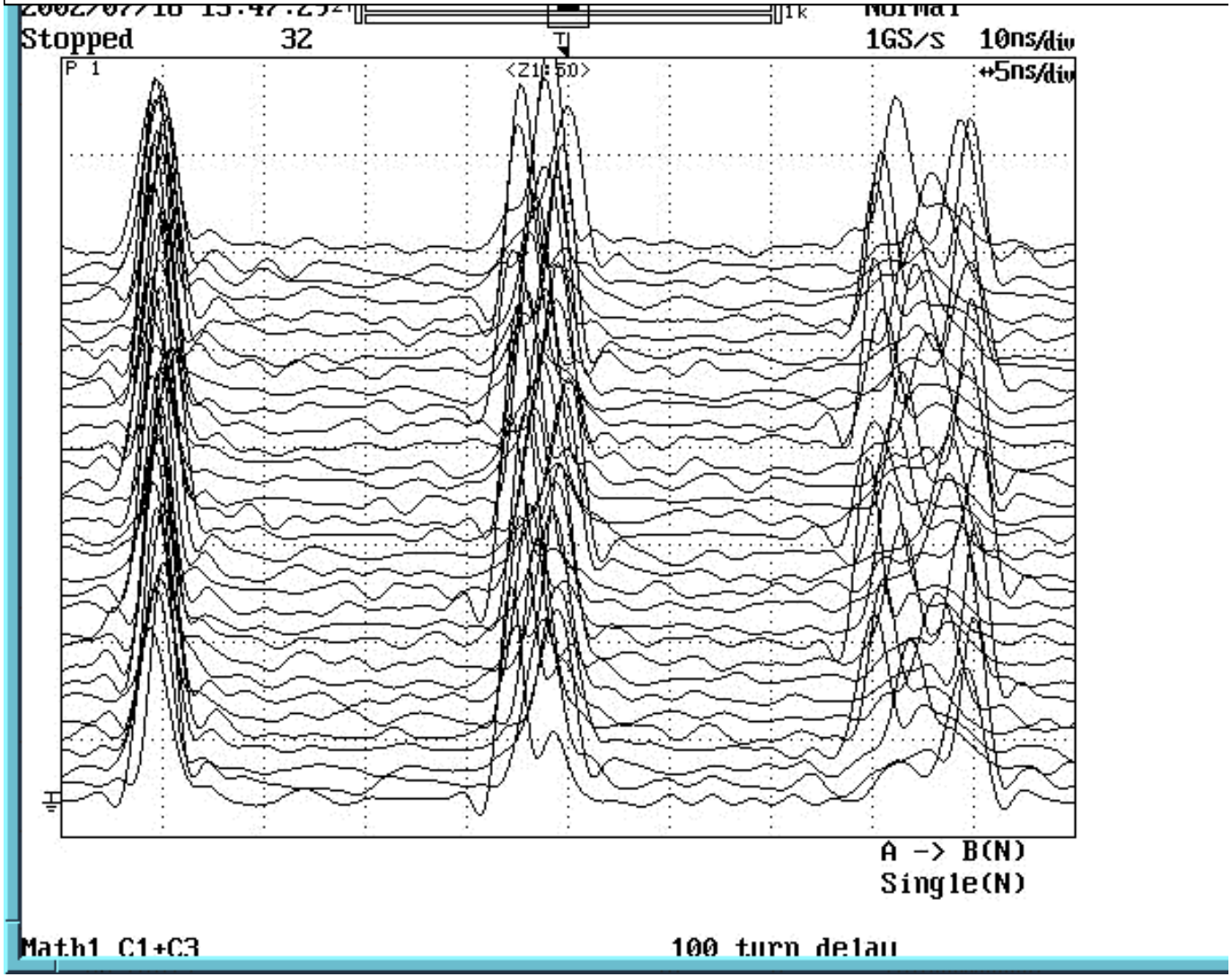
2. the blow-up occurs not in all bunches
3. recently commissioned bunch-by-bunch longitudinal damper (J.Steimel, C.Y.Tan) solved the issues (no blow-up in 6 stores #1569-1595 with the damper ON – see below - and there was double blowup in yesterday's store #1612 when the damper was OFF)


X: GxPA 1: shot data
Store #1578
Thu 25-JUL-2
T:IBEAM
.Mau 1E12
T:SBDMS
.Inst1 NSEC
T:LDM0IF
.Mau VOLT
C:B0PBSM
.CDF HZ
C:B0PAGC
.CDF HZ
10
3
.5
8
2.7
.3
6
2.4
.1
4
2.1
-.1
2
1.8
-.3
0
1.5
-.5
2000
80000
1600
60000
1200
40000
800
20000
400
0
0
10:30:00
13:30:00
16:30:00
19:30:00
22:30:00
T1 = Wed Jul 24 10:30:00 2002
T2 = Wed Jul 24 22:30:00 2002

Coherent: c) “dancing“ (un)coalesced bunches

- intensity dependent, large amplitudes (>1 rad at 150 GeV), slowly decohere, depends on bunch position, bunches are weakly coupled

Recently commisioned digital Mountain Range Display, Ron Moore



Instabilities #2: Incoherent(?):

a) bunch length growth during store: we had two dedicated stores with 3 trains of different intensity bunches (60e9/bunch to about 200e9/bunch) and inboth stores observed NO dependence of *d sigma_s/ dt* on bunch intensity (V.Shiltsev, S.Danilov – ORNL)

b) but SDA data analysis shows exactly opposite in many regular HEP stores (Paul Lebrun) --??

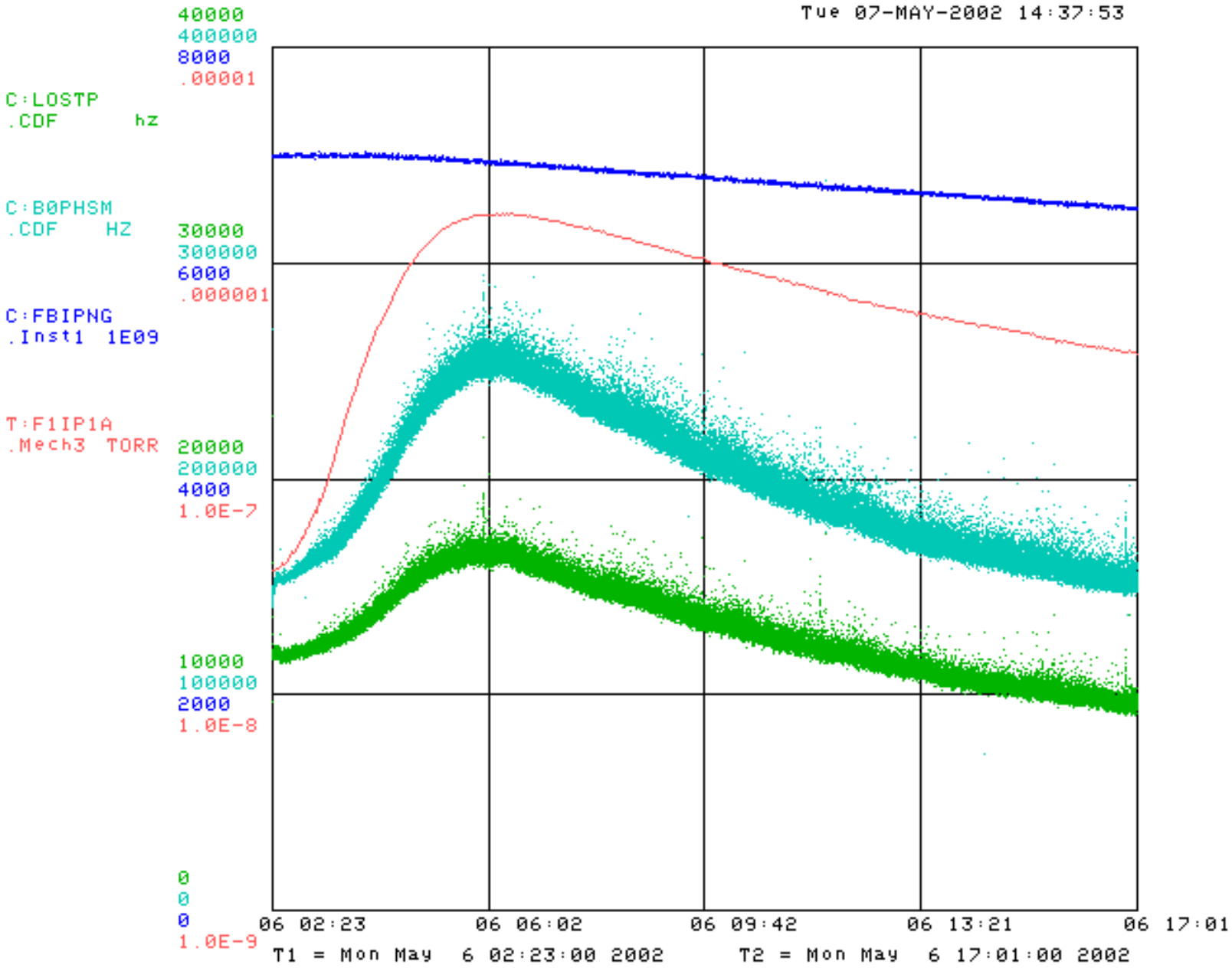
c) Wolfram Fischer of BNL has analyzed proton loss on ramp in after-shutdown stores (>12%) and concluded that it's due to large chromaticity tune modulation ($dQ=C\ dp/p \approx 0.02$)- see Tev-Note-2002/12. Recently, we performed direct check with 3 different intensity but same dp/p bunches and observed different %-losses → the loss is either intensity dependent or, more likely, dependent on transverse emittance

- Action items concerning instabilities:

1. build and install transverse bunch-by-bunch dampers to increase proton intensity and (possibly) reduce tev chromaticity (J.Steimel, C.Y.Tan) – 2 mos
2. build diagnostics to observe higher-order head-tail modes in betatron motion (SyncLite? Short pick-up? RFI) – 3 mos
3. explore longitudinal bunch-by-bunch damper operation at 150 GeV (ramp? C.Y.Tan) – 1 month
4. develop theoretical model of "dancing" bunches (V.Balbekov, V.Lebedev, G.Stupakov/SLAC) - ??
5. further experimental studies of the TeV RF noise (Gennady and Tamir of TD, J.Reid) – 6 mos
6. futher experimental studies of d sugma_s/dt and loss on ramp (Tev group)

Detector background/Losses:

- F11 ferrite outgassing → losses



- The effect was used to estimate average Tev vacuum ≈1.5e-9 Torr (R.Moore, V.Shiltsev)
- Fixed during June shutdown (Bruce+Mech.Support)
- outgasing experiments during shutdown allowed to estimate vacuum in the B0 and D0 P≈5e-9 Torr (Ron, Bruce) – order(s) of magnitude better than thought before
- Alvin et.al have separated different types of losses during collisions: (gas:Rf bucket:luminosity)=(4:2:1)
- a simple experiment with periodically varied TEL current confirmed that amount of the DC beam grows with time in store (V.Shiltsev, Alvin)
- (…detectors complain a bit less than before… are they happy with just luminosity?)

- we plan to:

  a) continue vacuum improvement (Bruce, Rosenberg/ANL) – next shutdown and later

  b) continue parasitic studies of losses (Alvin, Tev) – ongoing

  c) develop better loss model and justify/optimize collimation system (N.Mokhov, S.Drozhdin, Lyudovic, Valery L., Ron, Alvin, etc.) – expect breakthru in 3 mos.